Use of Rate of Force Development in Field Testing of Ice-Hockey Players

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ABSTRACT

Introduction: Ice hockey is a power-speed sport played on ice. The surface specification is very different from a normal surface, so looking for the most appropriate measurements and specific off-ice tests is important to define ice hockey performance better. Therefore, the main purpose of this research was to determine the relationship between the rate of force development (RFD) in back squats with commonly used off-ice and on-ice tests. Methods: The research involved a junior ice hockey team with 15 players (181.8 ± 4.1 cm; 80.7 ± 8.8 kg; 18.4 ± 0.9 yrs) playing in the highest junior competition of Czech hockey. Players performed all tests in one day divided into two blocks – off-ice block (OFF) in the morning and on-ice block (ON) in the afternoon, respectively. The OFF contained a 30 m sprint test with a 15 m split (SP15; SP30), plyometric tests (broad jump - BJ; countermovement jump - CMJ), and a velocity squat protocol (VSP). Finally, in the ON, speed and coordination tests were performed: 30 m forward skating with 15 m split (FW15 and FW30); 30 m backward skating with 15 m split (BW15 and BW30); Weave agility test (WAT); Transition test (TT) and Pro-agility test (PAT). Results: No significant results were found between the RFD and coordination tests (TT, WAT, PAT) and CMJ. Significant correlations were found between RFD40kg and SP30 ($r = -.865$; $p < .01$) and BJ and RFD40kg, respectively ($r = .649$; $p < .05$). However, as the back squat loads increase, the correlation strength decreases between RFD and SP30 ($r = -.677$; $p < .01$ for RFD50kg and $r = -.560$; $p < .05$ for RFD60kg). Furthermore, a strong degree of correlation was observed between RFD40kg and FW15 ($r = -.699$; $p < .05$) and also FW30 ($r = -.705$; $p < 0.05$). Conclusion: The study results show a significant relationship between RFD and commonly used off-ice and on-ice tests.

Keywords. Ice hockey; field testing; rate of force development; RFD; velocity training

INTRODUCTION

To maximise the athlete's performance, it is necessary to use such means that a performance transfer from a nonspecific environment to a specific one. In ice hockey, the development of strength, power, and speed is mainly trained in a nonspecific environment (Boucher et al., 2020; Delisle-Houde et al., 2019; Farlinger et al., 2007; Janot et al., 2015; Krause et al., 2012; Runner et al., 2016). In addition to plyometrics and speed tests, strength exercises with nonmaximal resistance can also be used to determine the power level of the athlete. In these exercises, in addition to the weight lifted (force), we are also interested in the speed of the barbell (velocity). The relationship between these quantities is represented by the force-velocity curve, which is inverse, i.e., as the force increases, the velocity decreases, and vice versa (Zatsiorsky & Kraemer, 2014).

Athletes must train with variable resistances and speeds, mainly applied in the preparatory phase. One of the goals of strength and conditioning training is to develop as much resistance as possible in the shortest possible time. The level of this ability is measured using a rate of force development (RFD) (Aagaard et al., 2002).

Although heavy squats are used most frequently in research to determine the strength of the lower extremities, their direct effect on on-ice performance is debatable (Dæhlin et al., 2017; Edman & Esping, 2013; Henriksson et al., 2016; Janot et al., 2015; Runner et al., 2016). According to Virgile (2019), lower body power production appears to be the most significant contributor to on-ice speed in ice hockey.

For this reason, this research aims to determine the relationship of power using RFD from the back squat with nonmaximal resistance with commonly used motor tests in ice hockey.

METHODS

Participants

Fifteen male elite junior ice hockey players (181.8 ± 4.1 cm; 80.7 ± 8.8 kg; 18.4 ± .9 yrs) participated in the study and were members of a junior ice hockey team in Brno, Czech Republic. All participants (or their legal representatives) signed an informed consent voluntarily agreeing to participate in the research. The Ethics Board of Masaryk University accepted the study.

Table 1. Description of the tested participants

Player	Height (cm)	Weight (kg)	Age (yr)
1	178	74.2	18.7
2	183	85	17.8
3	181	79.4	17
4	185	86.4	18.5
5	187	106.1	19.5
6	177	70.6	18.2
7	180	77.1	19.4

8	183	84.5	19.5
9	184	89.1	17.5
10	185	76.7	17.6
11	186	81.3	17.5
12	182	77.5	18
13	174	74.8	19.6
14	187	79.6	17.6
15	175	68.5	19.5

Test design

The collection of demographic data and consent to participate in the research was carried out the day before the intervention. Participants were instructed to limit secondary physical activities 24 hours before testing. The use of ergogenic substances and other stimulants was prohibited during the testing. The test day was divided into two blocks: off-ice block (OFF) in the morning and on-ice block (ON) in the afternoon. Both blocks were preceded by a team warm-up that lasted 10 minutes.

The OFF contained a 30 m sprint test with a 15 m split (SP15; SP30), plyometric tests (broad jump - BJ; countermovement jump - CMJ), and a velocity squat protocol (VSP). Speed tests were measured using timing photocells (Brower Timing Systems®, Salt Lake City, UT), CMJ was monitored using My Jump 2 (My Jump Lab®, Carlos Balsalobre, Madrid, Spain), and BJ using a Tape measure. Two trials were performed for each test, and the best score was selected for analysis. An extra attempt was allowed in case of a mistake.

The VSP was performed for three repetitions with gradually increasing loads of 40-50-60-70-80 kg depending on the squat velocity. Performance measurement was monitored using the TENDO Power Analyser (Tendo Sport®, Trenčín, Slovakia).

When the weight of the barbell was reached, when its speed exceeded the limit of 0.75 m/s in the concentric phase, the protocol was terminated. The given speed is considered the borderline area for strength-speed performance, approximately 70 % 1RM (Balsalobre-Fernández & Torres-Ronda, 2021).

The best repetition with the highest power was selected for each weight from the measured values, from which the average RFD was calculated. The formula of the average RFD is calculated in the same way as the index of explosiveness (IES) from peak force and time to peak force (Zatsiorsky & Kraemer, 2014):

$$IES = \frac{peak\ Force}{Time\ to\ peak\ Force}$$

Finally, speed and coordination tests were performed in the ON - 30 m forward skating with 15 m split (FW15 and FW30); 30 m backward skating with 15 m split (BW15 and BW30); Weave Agility Test (WAT); Transition test (TT) and Pro-agility test (PAT). Measurements were made using photocells (Brower Timing Systems®, Draper, UT). The participants underwent two trials, and the best score was selected for analysis. An extra attempt was allowed in case of a mistake. The layout of the ON is graphically represented in Figure 1.

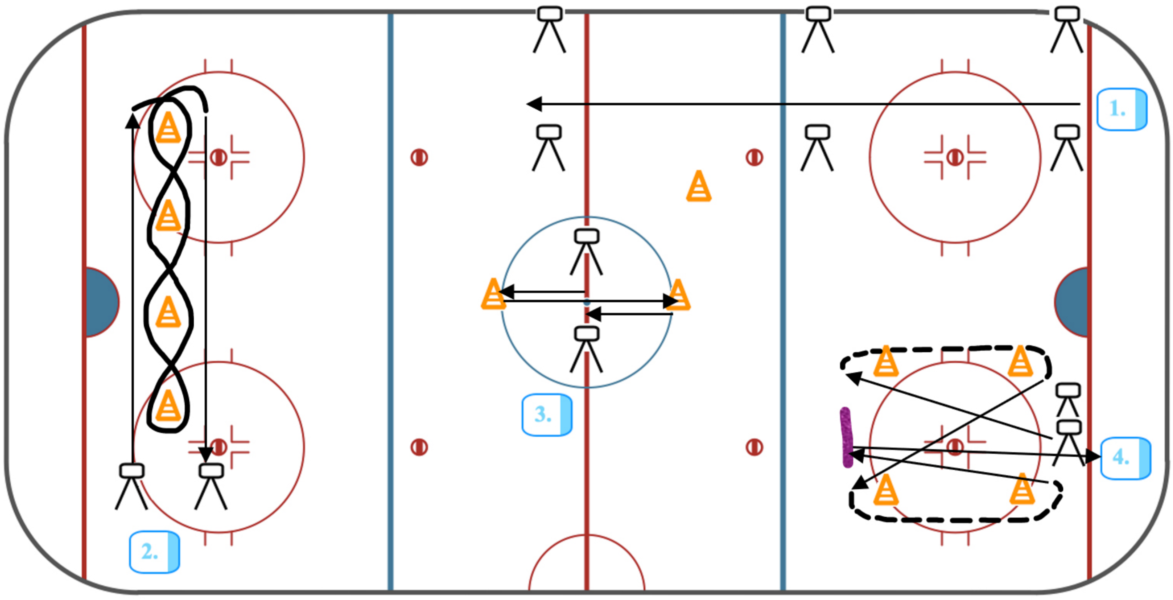

Figure 1. Visual representation of the ON (Note: 1. = FW15, FW30, BW15, BW30; 2. = WAT; 3. = PAT; 4. = TT)

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Macintosh, Version 28.0 (IBM Corp., Armonk, NY) program. Descriptive data were summarised as mean ± standard deviation (SD). Due to the lower number of respondents, Spearman's correlation coefficient was used for statistical analysis, the strength of which is divided into categories in the attached table no.2.

Table 2. The Strength of Spearman's Correlation

Spearman correlation	
.00 - .19	Very weak
.20 - .39	Weak
.40 - .59	Moderate
.60 - .79	Strong
.80 – 1	Very strong

RESULTS

The results are shown in Tables 3-5. Tables 3 and 4 describe the mean results and the standard deviation of the OFF and the ON, respectively. The resulting correlations of the RFD with other tests and statistical significance are shown in Table 5. The strength of the correlation is visually represented using a blue color scale.

Table 3. Results from the OFF testing

	Mean	SD
SP15 (s)	2.40	.08
SP30 (s)	4.29	.14
BJ (cm)	261	12
CMJ (cm)	50.1	5.3
RFD (N/s)		
40 kg	5857	1239
50 kg	6545	1060
60 kg	6723	1341
70 kg	6750	1102
80 kg	7255	1368

Table 4. Results from ON testing

	Mean	SD
FW15 (s)	2.51	.12
FW30 (s)	4.30	.16
BW15 (s)	3.01	.15
BW30 (s)	5.16	.23
WAT (s)	10.53	.28
TT (s)	15.55	.30
PAT (s)	4.79	.18

There were no significant correlations with the RFD and TT (r = -.287), WAT (r = -.375), PAT (r = -.469; p = .124), BW15 (r = -.473; p = .121), BW30 (r = -.396) and CMJ (r = .219). The significant RFD correlations with SP15 (r = -.639), SP30 (r = -.865), BJ (r = .649), FW15 (r = -.699) and FW30 (r = -.705) were measured at 40 kg. For the RFD50kg, correlations with SP15 and BJ were also observed, but only with moderate strength (r = -.536 and r = .561). As the back squat loads increase, the correlation strength shows a decreasing trend between the RFD and SP30 (r = -.677; r = -.560; r = -.653 and r = -.549).

Table 5. Spearman correlation results

	SP15	SP30	BJ	CMJ	FW15	FW30	BW15	BW30	PAT	WAT	TT
RFD 40 kg	-.639*	-.865**	.649*	.219	-.699*	-.705*	-.473	-.396	-.469	-.375	-.287
RFD 50 kg	-.536*	-.677**	.561*	.160	-.132	-.166	.052	.016	-.113	.093	.107
RFD 60 kg	-.474	-.560*	.406	.022	.002	- .059	.271	.132	-.103	.108	.093
RFD 70 kg	-.350	-.653*	.541*	.027	-.189	-.222	-.044	-.183	-.194	-.007	-.128
RFD 80 kg	-.427	-.549*	.504	.000	-.059	-.070	-.027	-.114	-.150	.134	.100

Note: *p < .05; ** p < .01

DISCUSSION

The primary methodological considerations for this study included a relatively small homogeneous sample (n = 15), which possibly limits the generalisability of our findings outside of elite-level hockey players.

As a significant finding of this study, FW30 and FW15 are strongly correlated with RFD40kg. There is no research, to our knowledge, that deals with the dependence between the exact quantities. Korte (2020) investigated a similar relationship with ice performance, applying a weighted CMJ for 20, 40, and 60 kg. He found a significantly strong correlation between CMJ with 40 kg and 30 m on-ice sprint ($r = -.686$; $p < .001$) and 15 m on-ice sprint ($r = -.634$; $p < .001$), which is similar to our findings for FW30 ($r = -.705$; $p < .05$) and FW15 ($r = -.699$; $p < .05$). Furthermore, at higher barbell weight, the strength of the correlation decreases to medium for both the 30 m distance ($r = -.592$; $p < .001$) and the 10 m distance ($r = -.516$; $p < .001$).

The explosive power of the lower extremity is very well tested and developed not only with CMJ but also with BJ (Blanár et al., 2019; Dobbs et al., 2015; Runner et al., 2016). Our research demonstrated a strong positive correlation between RFD and BJ ($r = .649$; $p < .05$). As mentioned by Maffiuletti et al. (2016), in their review, RFD is best trained by exercises that involve explosive muscle contraction; therefore, the relationship we found between BJ and RFD is justified.

The RFD did not correlate with any on-ice agility test or BW15 and BW30. We explain this by the fact that in agility tests, in addition to speed and explosive muscle contraction, more factors manifest themselves, such as skating technique, changes in direction speed (CODS), balance, and coordination (Behm et al., 2005; Dawes et al., 2012; Hojka et al., 2016). In addition, Henriksson et al. (2016) examined unilateral and bilateral jump variations in on-ice agility and found that the strongest correlations of on-ice agility tests existed with unilateral jumps.

Allisse et al. (2017) documented the development of performance profiles of elite ice hockey players of the age group over 12 months and found that in the off-season, a reverse skating speed test showed a significant deterioration in performance. This may be due to the need for more specific stimuli in off-ice training and long periods without on-ice training, where this skill is best trained. This may explain the inconsistent results of other research looking at BW tests and off-ice performance assessments (Delisle-Houde et al., 2019; Runner et al., 2016). Our research was carried out at the end of the training period, so even here, the deterioration of the BW performance could be reflected. The accurate precision of the relationship needs to be taken with a grain of salt.

A very strong correlation was found between RFD and SP30. SP15 only correlates with RFD40kg and RFD50kg. In the acceleration phase, the athlete is in a greater forward bend, the foot's contact time with the ground is higher, and he participates to a greater extent in the movement and horizontal force (Kawamori et al., 2013). During acceleration, when the athlete moves to the maximum velocity phase, the torso straightens, the foot's contact with the ground is shortened, and the contribution of horizontal force to the movement is also reduced (Nagahara et al., 2018). A significant difference between these phases was investigated by Hunter et al. reported that sprint velocity at 16 m after a start was significantly correlated with horizontal force. This leads to the consideration that the maximum velocity phase from the point of view of biomechanics corresponds more to the execution of the back squat than the acceleration one.

The correlation decreased with increasing weight. From the references mentioned above, the correlation between SP30 and RFD decreases because the higher weight reduces the speed of the squat execution. Thus the explosive power activity of the lower limbs was not optimal (Kraemer & Spiering, 2006). More research is needed to confirm this assumption and for a definitive conclusion.

CONCLUSION

The study aimed to determine the power relationship using RFD from the back squat with nonmaximal resistance with commonly used motor tests in ice hockey. The TENDO power analyser was used to measure barbell velocity. RFD was calculated as IES from peak force and time to peak force (Zatsiorsky & Kraemer, 2014). From off-ice tests, SP30 correlated best with RFD40kg ($r = -.865$; $p < .01$), and from on-ice tests showed a strong correlation with FW30 ($r = -.705$; $p < .05$).

These results provide new insight into the relationship between force-velocity and on-ice performance because no other research has yet dealt with the same research problem.

The findings should help clarify the importance of testing the nonmaximal resistance squat with rapid execution as a middle measure of performance between bodyweight jumps and heavy squats.

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